

# About mechanics of the structured particles

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The principles of creation of the mechanics of structured particles in the frame of the Newton's laws are considered. The explanation how this mechanics leads to the account of dissipative forces is offered. It is discussed why the motions of the system determine by two type of symmetry: symmetry of the system and symmetry of space and how it leads to two types of energy and forces accordingly. It is shown how the mechanics of the structured particles leads to thermodynamics, statistical physics and kinetics.

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## I. INTRODUCTION

The Newton's motion equation is gained on the basis of the model bodies in the form of the material points (P) and solid bodies. Such idealization of models of real bodies leads us to the second law of Newton. According to this law, the acceleration of MP is proportional to the potential force which acts on it [1, 2]. The work of this force is equal to their integral along the way. The energy conservation law of MP from here follows. In connection with this law the dynamics of MP is determined by two types of energy: the kinetic energy and potential energy. Along trajectory of MP the sum of these types of energy is constant. The MP motion is reversible. It follows from the Newton's second law.

All bodies in the nature have a structure. They have the internal energy which is caused by relative motion of the body's elements. Therefore the works of the external forces change not only the body's motion energy but the internal energy also. However the Newton's motion equation, which has been constructed on the basis of models of structureless bodies, does not include the terms responsible for the change an internal energy. In practice the change an internal energy are taken into account by addition to the Newton's motion equation of the empirical force of a friction.

The work of the frictional forces defines the dissipative part of motion energy which goes to the body's internal energy and dissipated in the environment [2]. The friction coefficient is taken from the experiment. Thus, the rigorous description of the dynamics of bodies in the frame of classical mechanics is absent. It is due to the simplification of the bodies models. We have assumed from here that for description of a motion of real bodies, the MP should be replaced on a structural particle and the motion equation for the structural particles should be obtained.

The great diversity of structural particles does not allow analyzing all types of energy dissipation. But we can select such relatively simple models that allow un-

derstanding the nature of dissipation in the framework of the laws of classical mechanics. We found that it is a system of potentially interacting material points.

The problem of description of the dissipative forces in the frame of the classical mechanics is similar to the problem of irreversibility. This problem was formulated by Boltzmann. All attempts to solve it without the use of statistical laws were till now unsuccessful. The generally accepted explanations of the irreversibility of today are based on probabilistic laws contradicting the determinism of classical mechanics [3]. Nevertheless, the explanation of irreversibility without attraction of probabilistic laws, if particles possess by the structure, can be offered [4, 5].

To find an approach to solving the irreversibility problem in the framework of the laws of classical mechanics, the dynamics of hard disks was studied in the beginning. As a result, it was found that the system, consisting of two interacting of disks subsystems, moves to equilibrium [4]. It has been shown that this is due to the transformation of energy of relative motion of subsystems into the motion energy of disks relative to the center of masses (CM) of the corresponding subsystem. The same mechanism of equilibration takes place for the structured particles (SP) where SP is equilibrium system consisting from a big enough number of potentially interacting MP.

Mechanic of SP can be constructed at following restrictions [6]: 1). Everyone MP is belonging to its SP during all process. 2). SP is in equilibrium during all time. The first restriction eliminates inessential complications related to the necessity to reconsider of SP structure due to transitions P between them. The second restriction is equivalent to the requirement of weak interacting which accepted in thermodynamics.

The aim of this paper is to show how the mechanics of SP can be constructed on the bases of a Newton's laws for MP. For this purpose the nature of the restrictions of classical mechanics is analyzed. The explanation of the necessity of the systems dynamics description on the basis of two types of symmetry: the symmetry of the system and the symmetry of the space are submitted. How from SP mechanics to come to thermodynamics, statistical physics and kinetics and how to introduce the concept of entropy into the classic mechanics are explained.

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## II. THE SYSTEM OF TWO MP

The basic principles for construct of the SP mechanics as well as the method of its construction can be illustrated on the example of system of two MP. The task of two MP is solved by transition to a coordinate system of CM [7]. In this case, the variables are separated. The nature of such separation of variables is connected with the emergence of a new quality of a system that is absent for MP. It is internal energy caused by the relative motions of system elements. The energy of two MP in laboratory coordinates of system (LS) has the form:

$$m(v_1^2 + v_2^2)/2 + U(r_{12}) + U^{env}(r_1) + U^{env}(r_2) = const(1)$$

where  $U(r_{12})$  is a potential energy of MP interaction;  $U^{env}(r_1)$ ,  $U^{env}(r_2)$  are potential energies for MP in an external field of forces;  $r_1, r_2$ -coordinates of MP;  $r_{12} = (r_1 - r_2)$ ;  $v_1, v_2$  are the velocities of MP.

The motion each MP is caused by two independent types of forces: forces of interaction MP and external forces. In the LS coordinate system the task is nonlinear because the motion of one MP depends from the motion of the other MP. Thus in the LS coordinates of system the MP motion are interdependent. Therefore the LS system is unacceptable for the description of dynamics of system. New variables are set as follows:  $R_2 = (r_1 + r_2)/2$ ,  $V_2 = \dot{R}_{12}$ , are coordinates and velocities for CM,  $v_{12} = \dot{r}_{12}$ . In these variables the system's energy is:

$$E = MV^2/2 + mv_{12}^2/4 + U(r_{12}) + U^{env}(R_2, r_{12}) \quad (2)$$

Here  $MV^2/2$  is a kinetic energy of CM system's motion. The energy  $mv_{12}^2/4 + U(r_{12})$  is a internal energy of system determined by forces of interaction MP and their relative motion;  $U^{env}(R_2, r_{12})$  is a potential energy of system in an external field.  $M = 2m$ .

Differentiating the energy (2) with respect to time, we get:

$$MV\dot{V} + mv_{12}\dot{v}_{12}/2 + F_{12}v_{12} + F_{R_2}^{env}V_2 + F_{r_{12}}^{env}v_{12} = 0(3)$$

where  $F_{12} = \partial U(r_{12})/\partial r_{12}$ ,  $F_{R_2}^{env} = \partial(U^{env})/\partial R_2$ ,  $F_{r_{12}}^{env} = \partial(U^{env})/\partial r_{12}$ .

If there is no external force field, the last two terms in eq. (3) are zero. Variables are separated and eq. (3) is integrable. If the external field exist but does not depend from  $r_{12}$  then last term in the eq. (3) is equal to zero and its breaks up on two independent equations:

$$MV_2\dot{V}_2 + F_{R_2}^{env}V_2 = D \quad (4)$$

$$mv_{12}\dot{v}_{12}/2 + F_{12}v_{12} = -D \quad (5)$$

Here the eq. (4) describes the motion of the CM system in an external field; the eq. (5) describes the relative motion MP which does not depend on exterior forces;  $D$  is a constant which could be chosen equal to zero. It means that when the external forces are homogeneous

the internal energy can't change. Thus in the first and second cases the motion of two MP is determined by the Newton's third law. In generally the exterior forces can change both the energy of system motion and internal energy.

Thus, on the example of the two-body system has shown that the energy of the system is split into two independent types by transition to the CM coordinates system. It is the internal energy which depends on the relative velocities of MP and the forces of their interaction. And it is the energy of the system motion in the field of external forces which depends on the coordinates of the CM and its velocity. We can see that by summarizing of the motion equation for LS, we exclude internal forces, leaving only the external forces. As a result we come to the system's motion equation in space. By subtracting these equations, we exclude the external forces and come to the equation defining the relative motion of the MP due to their interaction forces. I.e. the system's motion, unlike the MP motion, is determined by two invariants: the energy of its motion and internal energy.

All bodies consist of micro-particles or molecules. Therefore they can be represented in the form of the SP whose position is determined by its CM. As shown on example of two MP, the motion of each MP should be determined in relative to the CM. Coordinates and velocities of the MP relative to the CM systems we will call micro variables, the coordinates and velocity of the CM systems we will call as macro variables. Since internal and external forces are independent, then these variables are also independent. Hence the two spaces variables in relevant micro and macro variables, also independent. I.e. the new variables divide the space of the generalized co-ordinates and velocities on two independent subspaces. One subspace is determined by the internal symmetries of the system, and the second subspace is determined by the symmetry of the outer space [8]. Thus the systems dynamics is defined by two types of symmetry: symmetry of the system which defined by distribution of its elements and character of their interactions, and symmetry of space in which the system moves. Hence, the energy of the system will be the sum of two invariants of motion: internal energy and the energy of motion of the system as a whole.

Since the energy, unlike the forces, is the additive function of dynamic parameters of the MP, the mechanics of SP conveniently builds basing on the energy function. Below we will obtain the expression for the energy of the system consisting from potentially interacting MP which will be written down in micro and macro dynamic variables.

## III. ENERGY OF THE MP SYSTEM

Let us take a system from  $N$  of potentially interacting a unit mass MP. The potentials in each point of space are additive. Therefore the force acting on a given MP is

equal to the sum of forces acting on it from all others MP and from the external forces. The forces between every one two MP are determined by distance between them. Thus the kinetic energy of system  $T_N$  can be represented as the sum of the kinetic energies of the MP.

So  $T_N = \sum_{i=1}^N mv_i^2/2$ . Potential energy is equal to the sum of potential energies of all MP in the field of the external forces and potential energies of MP pair interactions among themselves which is  $U_N(r_{ij}) = \sum_{i=1}^{N-1} \sum_{j=i+1}^N U_{ij}(r_{ij})$ , where  $i, j = 1, 2, 3 \dots N$  are the numbers of MP,  $r_i, v_i$  are coordinates and velocities of the  $i$ -th MP,  $r_{ij} = r_i - r_j$ . Hence, full energy of system is equal to  $E = E_N + U^{env} = T_N + U_N + U^{env} = \text{const}$ .

It is obvious that kinetic energy of system includes the energy of its motion in the field of external forces,  $T_N^{tr}$  and kinetic energy of relative motion,  $T_N^{ins}$  caused by interactions MP among themselves. I.e.,  $T_N = T_N^{ins} + T_N^{tr}$ . We will write down the velocities of everyone MP in the form of the sum:  $v_i = V_N + \tilde{v}_i$ , where  $V_N = \dot{R}_N$ ,  $R_N = (\sum_{i=1}^N r_i)/N$ ,  $\sum_{i=1}^N \tilde{v}_i = 0$ . Hence  $T_N = \sum_{i=1}^N mv_i^2/2 = M_N V_N^2/2 + \sum_{i=1}^N m\tilde{v}_i^2/2$ . It means that unlike one MP the total kinetic energy of motionless system is equal to the sum kinetic energies of MP determined by their velocities relative to the CM. I.e. one part of kinetic energy of system is connected with motion of the MP relative to the CM and the second part is connected with the motion of the system CM. Hence, the velocity of system is determined by the velocity of its CM whose position is defined by a radius-vector  $R_N$ .

Thus the system's energy consists of the kinetic energy of the MP motion relative to the CM and the potential energy of their interaction. The sum of this energy called the internal energy of the system. Then the energy can be written as a sum of internal energy plus the system's energy in the field of external forces. I.e.:

$$E_N = T_N^{tr} + E_N^{ins} + U^{env}, \quad (6)$$

where  $E_N^{ins} = T_N^{ins} + U_N$ , is internal energy,  $T_N^{ins} = \sum_{i=1}^N m\tilde{v}_i^2/2$  is a kinetic part of internal energy,  $U_N$  is a potential part of internal energy, determined by the interactions of MP.

Quadratic function of the kinetic energy can be expressed through a quadratic function in which arguments are the velocities of the MP in relative to the CM and the velocity of the CM system. This conclusion is follow from the equality:  $\sum_{i=1}^N mv_i^2/2 = m/(2N) \{ V_N^2 + \sum_{i=1}^{N-1} \sum_{j=i+1}^N v_{ij}^2 \}$

(a). The first term in (a) is the kinetic energy of the CM motion. The second term is the kinetic part of the internal energy determined by the relative velocities of MP.

Let's transform the energy  $T_N$  by replacement:  $v_i = V_N + \tilde{v}_i$ , where  $\tilde{v}_i$  is a MP velocities relative to the CM. As  $\sum_{i=1}^N \tilde{v}_i = 0$ , then  $T_N = M_N V_N^2/2 + \sum_{i=1}^N m\tilde{v}_i^2/2$ . Using

(a) we will find:  $\sum_{i=1}^N m\tilde{v}_i^2/2 = \sum_{i=1}^{N-1} \sum_{j=i+1}^N v_{ij}^2$ . Therefore

$$T_N^{ins} = \sum_{i=1}^N m\tilde{v}_i^2/2 = \sum_{i=1}^{N-1} \sum_{j=i+1}^N v_{ij}^2.$$

Thus the law of energy conservation for the system can be formulated as follows: the sum of the system's kinetic energy of motion, its internal energy and of the potential energy in the external field of forces always is a constant along the trajectory of the CM. The difference of the energy conservation laws for the system and for MP leads to a qualitative distinction for their motions. Indeed, the trajectory MP is defined by transformation of potential energy of an external field only into the kinetic energy of its motion. But the trajectory of system is defined by transformation of potential energy of an external field both to its kinetic energy and to internal energy. The natural variables that define these types of energy are macro and micro variables.

#### IV. THE SYSTEM'S MOTION EQUATION

There are basic differences of dynamics of the systems possessing structure and the sizes, from dynamics of MP. The motion of MP is uniquely determined by the point in space. But SP motion is determined by the area of space occupied with it. Therefore for unequivocal definition of dynamics of system it is necessary to know, both change of its kinetic energy of the system motion and change of internal energy as energy of an external field goes on change of these two types of energy. The system's motion depends from its sizes if the is exist the spatial nonhomogeneity of external forces.

Another fundamental difference between the dynamics of MP and the dynamics of the system base on the fact that for one MP the principle of superposition of forces is valid, while for the different MP it is not so. Indeed the change of the internal energy has a place when the sum of internal forces is equal to zero. Therefore if to summarize the equations of motion for each MP, we will lose the terms which determine the change of the internal energy. But the system's motion is determined by the change of two types of energy: the system's motion energy and internal energy. Therefore the motion equation should be obtained from the energy equation in the variables that determine the motion of its CM and motion of the MP relative to the CM.

Differentiating the energy of the system (6) over time we obtain [5, 6]:

$$V_N M_N \dot{V}_N + \dot{E}_N^{ins} = -V_N F^{env} - \Phi^{env} \quad (7)$$

Here  $F^{env} = \sum_{i=1}^N F_i^{env}(R_N, \tilde{r}_i)$ ,  $\dot{E}_N^{ins} = \dot{T}_N^{ins}(\tilde{v}_i) +$

$\dot{U}_N^{ins}(\tilde{r}_i) = \sum_{i=1}^N \tilde{v}_i(m\dot{\tilde{v}}_i + F(\tilde{r})_i)$ ,  $\Phi^{env} = \sum_{i=1}^N \tilde{v}_i F_i^{env}(R_N, \tilde{r}_i)$ ,  $r_i = R_N + \tilde{r}_i$ ,  $M_N = mN$ ,  $v_i = \dot{V}_N + \tilde{v}_i$ ,  $F_i^{env} = \partial U^{env} / \partial \tilde{r}_i$ ,  $\tilde{r}_i, \tilde{v}_i$  are the coordinates and velocity of  $i$ -th particle in the CM system,  $R_N, V_N$  are the coordinates and velocity of the CM system.

The equation (7) represents the balance of the energy of the system of material points in the field of external forces.

The first term in the left-hand side of the equation determines the change of kinetic energy of the system -  $\dot{T}_N^{tr} = V_N M_N \dot{V}_N$ . The second term determines the change of internal energy of the system. This energy dependent on coordinates and velocities of material points relative to the CM.

The right-hand side corresponds to the work of external forces changing the energy of the system. The first term changes the systems motion energy. The second term determines the work of forces changing the internal energy.

Now let us take the external forces which scale of heterogeneity is commensurable with the systems scales. In this case we can write:  $F^{env} = F^{env}(R + \tilde{r}_i)$  where  $R$  is a distance to the CM. Let us assume that  $R \gg \tilde{r}_i$ . In this case the force  $F^{env}$  can be expanded with respect to a small parameter. Leaving in the expansion terms of zero and first order we can write:  $F_i^{env} = F_i^{env}|_R + (\nabla F_i^{env})|_R \tilde{r}_i \equiv F_{i0}^{env} + (\nabla F_{i0}^{env}) \tilde{r}_i$ . Taking into account that  $\sum_{i=1}^N \tilde{v}_i = \sum_{i=1}^N \tilde{r}_i = 0$  and  $\sum_{i=1}^N F_{i0}^{env} = N F_0^{env} = F_0^{env}$ , we get from eq. (7):

$$V_N(M_N \dot{V}_N) + \sum_{i=1}^N m \tilde{v}_i (\dot{\tilde{v}}_i + F(\tilde{r})_i) \approx \\ \approx -V_N F_0^{env} - (\nabla F_{i0}^{env}) \sum_{i=1}^N \tilde{v}_i \tilde{r}_i \quad (8)$$

The work of the potentially part of force,  $F_0^{env}$ , change the system's motion energy. The term in the right-hand side has a first order of smallness as the condition  $R \gg \tilde{r}_i$  does not mean smallness of the  $\tilde{v}_i$ . This term is proportional of the gradient of external force and determines the work on change of internal energy. Its variation can't be expressed by the integral of the gradient of scalar function on the way. It is because the change of internal energy is a sum of work of external forces in change the relative motion of MP. Therefore these forces can be expressed through the effectiveness of the change in internal energy. This can be done so. Multiplying eq.(7) by  $V_N$  and dividing by  $V_N^2$  we find the equation of system motion [6]:

$$M_N \dot{V}_N = -F^{env} - \alpha_N V_N \quad (9)$$

where  $\alpha_N = [\dot{E}_N^{ins} + \Phi^{env}] / V_N^2$ .

The second term in the right-hand side defines a non-potential part of forces whose work changes the internal

energy. If the external field of force is homogeneous or when the forces between MP are much more then acting on the system of the external forces, this term is equal to zero and the eq. (9) becomes the Newton's motion equation.

Thus, to obtain the motion equation for the structured body, it is necessary to execute consistently the following operations. Firstly, it is necessary to present a body as a system of micro particles. By transition to micro and macro parameters we present the system's energy as a sum of the motion energy and an internal energy. Then we obtain the equation of energy flow between these types of energy. From here we will come to a system's motion equation which takes into account non-potential force changing its internal energy.

It is important to note that the eqs. (6-9) strictly follow from Newton's laws for MP. Therefore, all properties of the systems dynamics follow from these laws.

## V. THE SYSTEM OF SP

The above equations are valid for the general case of any systems of potentially interacting MP in the external field of forces. In generally due to the nonlinearities they are not integrable. But integration is possible if the system represents as a set of SP. The equilibrium of SP means that it can be split on the rather large equilibrium subsystems which are motionless relative to each other. The SP internal energy is the sum of the internal energies of subsystems. I.e. the collective processes of energy, momentum and mass flows into SP are absent. Therefore at feeble enough action on SP not breaking equilibrium, its motion will be determined by the change of the motion energy and an internal energy.

In the approach of the local equilibrium approximation any non-equilibrium system can be represented by a set of SP which has a relative motion to each other. In the thermodynamic limit at enough weak interactions, each of the SP during the entire process can be regarded as equilibrium [9]. Then the dynamics of non-equilibrium systems can be described by the eq. (9).

Let us the system consists of two SP:  $L$  and  $K$ . Let us  $L$  is the number of elements in the  $L$ -SP and  $K$  is the number of elements in  $K$ -SP, i.e.  $L + K = N$ .

Let us CM for two SP motionless, i.e.  $LV_L + KV_K = 0$ , where  $V_L$  and  $V_K$  are velocities of  $L$  and  $K$  equilibrium subsystems relative to the CM system. Differentiating the energy of the system with respect to time, we obtain:  $\sum_{i=1}^N v_i \dot{v}_i + \sum_{i=1}^{N-1} \sum_{j=i+1}^N v_{ij} F_{ij} = 0$ , where  $F_{ij} = U_{ij} = \partial U / \partial r_{ij}$ . In order to derive the equation for  $L$ -SP, in the left-hand side of the equation we leave only terms determining change of kinetic and potential energy of interaction of  $L$ -SP elements among themselves. All other terms we displace into the right-hand side of the equation and combine the groups of terms in such a way that each group contains the terms with identical velocities.

In accordance with Newton equation, the groups which contain terms with velocities of the elements from  $K$ -SP are equal to zero. As a result the right-hand side of the equation will contain only the terms which determine the interaction of the elements  $L$ -SP with the elements  $K$ -SP.

Thus we will have:  $\sum_{i_L=1}^L v_{i_L} \dot{v}_{i_L} + \sum_{i_L=1}^{L-1} \sum_{j_L=i_L+1}^L F_{i_L j_L} v_{i_L j_L} = \sum_{i_L=1}^L \sum_{j_K=1}^K F_{i_L j_K} v_{j_K}$  where double indexes are introduced to denote that a particle belongs to the corresponding system. If we make substitution  $v_{i_L} = \tilde{v}_{i_L} + V_L$ , where  $\tilde{v}_{i_L}$  is the velocity of  $i_L$  particle relative to the CM of  $L$ -SP, we obtain the equation for  $L$ -SP. The equation for  $K$ -SP can be obtained in the same way. The equations for two interacting systems can be written as [6, 11]:

$$V_L M_L \dot{V}_L + \dot{E}_L^{ins} = -\Phi_L - V_L \Psi \quad (10)$$

$$V_K M_K \dot{V}_K + \dot{E}_K^{ins} = \Phi_K + V_K \Psi \quad (11)$$

Here  $M_L = mL, M_K = mK, \Psi = \sum_{i_L=1}^L F_{i_L}^K$ ;  $\Phi_L = \sum_{i_L=1}^L \tilde{v}_{i_L} F_{i_L}^K$ ;  $\Phi_K = \sum_{i_K=1}^K \tilde{v}_{i_K} F_{i_K}^L$ ;  $F_{i_L}^K = \sum_{j_K=1}^K F_{i_L j_K}$ ;  $F_{j_K}^L = \sum_{i_L=1}^L F_{i_L j_K}$ ;  $\dot{E}_L^{ins} = \sum_{i_L=1}^{L-1} \sum_{j_L=i_L+1}^L v_{i_L j_L} [\frac{m \dot{v}_{i_L j_L}}{L} + F_{i_L j_L}]$ ;  $\dot{E}_K^{ins} = \sum_{i_K=1}^{K-1} \sum_{j_K=i_K+1}^K v_{i_K j_K} [\frac{m \dot{v}_{i_K j_K}}{K} + F_{i_K j_K}]$ .

The equations (10, 11) are equations for interactions between SP. They describe energy exchange between SP. Independent variables are macro-parameters and micro-parameters. Macro-parameters are coordinates and velocities of the motion of CM of systems. Micro-parameters are relative coordinates and velocities of material points. Therefore the equation of system interaction binds together two types of description: on the macro-level and on the micro-level. The description on the macro-level determines dynamics of an SP as a whole and description on the micro-level determines dynamics of the elements of an SP.

The potential force,  $\Psi$ , determines the motion of an SP as a whole. This force is the sum of potential forces acting on the elements of one SP from the other system.

The forces determined by terms  $\Phi_L$  and  $\Phi_K$  transform the motion energy of SP into their internal energy as a result of chaotic motion of elements of one SP in the field of forces of the other SP. As in the case of the system in the external field, these terms are not zero only if the characteristic scale of inhomogeneity of forces of one system is commensurable with the scale of the other system. The work of such forces causes violation of time symmetry for SP dynamics.

The equations for systems motion corresponding to the equations (10,11) can be written as:

$$M_L \dot{V}_L = -\Psi - \alpha_L V_L \quad (12)$$

$$M_K \dot{V}_K = \Psi + \alpha_K V_K \quad (13)$$

where  $\alpha_L = (\dot{E}_L^{ins} + \Phi_L)/V_L^2$ ,  $\alpha_K = (\Phi_K - \dot{E}_K^{ins})/V_K^2$ ,

The eqs. (12, 13) are written down for SP which are considered equilibrium during all process of interaction. In this case we can neglect by the energy, momentum and mass flows into SP. Due to equilibrium of SP its internal energy can't be transformed into SP motion energy. This follows from the law of conservation of momentum, according to which neither any internal MPs motions can change of SP velocity. From here we come to a conclusion about irreversibility of SP dynamics. Therefore we can call the " $\alpha_L$ ", " $\alpha_K$ " as a friction coefficients.

Dynamics of non-equilibrium systems are determined by the eqs. (12, 13). Consequently the Lagrange Hamilton and Liouville equations for the systems whose elements are the SP will also be determined by these equations. It is well known that the Hamilton principle for MP derived from differential D'Alembert principle using Newton equation for MP [2]. For this purpose the time integral of virtual work  $\delta \omega^e$  done by effective forces is equated to zero. Integration over time is carried out provided that external forces possess a power function. It means that the canonical principle of Hamilton is valid only for cases when  $\sum F_i \delta R_i = -\delta U$ , (b) where  $i$  is a particle number, and  $F_i$  is a force acting on this particle. But for interacting SP the condition of conservation of forces is not fulfilled because of the presence of a non-potential component. Therefore in the equations of Lagrange, Hamilton and Liouville for systems from SP the terms caused by non-potentiality of collective forces are appeared. In this case the Liouville equation looks like [4, 6]:

$$df/dt = - \sum_{L=1}^R \partial F_L / \partial V_L \quad (14)$$

Here  $f$  is a distribution function for a set of SP,  $F_L$  is a non-potential part of collective forces acting on the SP,  $V_L$  is the velocity of  $L$ -SP.

The right-hand side of the equation is determined by the efficiency of transformation of the SP motion energy into their internal energy. For non-equilibrium systems the right-hand side is not equal to zero because of non-potentiality of forces changing the internal energy.

The state of this system can be defined in the phase space which consists of  $6R - 1$  coordinates and momentums of SP, where  $R$  is a number of SP. Location of each SP is given by three coordinates and their moments. Let us call this space us  $S$ -space for SP in order to distinguish it from the usual phase space for MP. It is caused by transformation of the motion energy of SP into their internal energy. The SP internal energy can't be transformed into the SP energy of motion as SP momentum can't change due to the motion of its MP. Therefore  $S$ -space is compressible because the internal energy will increase until the relative motion of SP did not disappear.

In connection with  $S$ -space it is necessary to redefine the geometrical concept of an interval [2] for systems

whose elements are the SP. Indeed, we have shown that the dynamics of the SP is determined by two types of symmetry: the internal symmetry and the symmetry of the space. Therefore the motion of the system is determined by two types of energy: kinetic energy of the SP and its internal energy. Each of these types of energy has its own type of forces. This is reflected in the fact that the geometry of motion of the SP, in contrast to the geometry of motion of the MP, is the sum of the squares of the two intervals, that can be written as [2, 7]:  $d\bar{s}^2 = ds_{tr}^2 + ds_{ins}^2$ . Here  $ds_{tr}^2$  is a square of an interval corresponding to SP motion energy,  $ds_{ins}^2$  - is a square of the interval corresponding to SP internal energy.

Thus, the square of the interval of a non-equilibrium system splits into the sum of the squares of the two intervals. The first one corresponds to the system motion while the second corresponds to its internal energy. These intervals are orthogonal since they satisfy the Pythagorean Theorem.

## VI. MECHANICS OF SP AND THERMODYNAMICS

Difficulties of substantiation of the empirical laws of thermodynamics based on fundamental laws of physics are connected with the reversibility of the Newton's motion equations. The reversibility is due to its constructing on the bases of unstructured body's models. Acceptance in attention of structure leads to occurrence of non-potential component of the collective forces of body's interaction changing their internal energy. For SP this energy can only increase due to the energy of its motion. It is equivalent to irreversibility of the SP dynamics. Let us explain this conclusion.

The presence of reversible dynamics for SP would mean that its internal energy is capable to pass into motion energy. In turn this would mean the possibility of increasing momentum of SP at the expense of its internal energy. But this contradicts the law of conservation of momentum. Indeed, for each of the equilibrium subsystems into which splits SP the sum of the velocities of MP in subsystems and sum of their interaction forces are equal to zero. But for appearing of SP momentum it is necessary that at least in one of subsystems the requirement of equality to zero of the sum of forces has been disrupted. It is impossible because according to a law of momentum conservation any of subsystems cannot acquire a relative velocity or due to internal MP motion or forces from unmovable subsystems. I.e. internal energy of the SP can't transform into the energy of its motion. It is equivalent to irreversibility. From the mathematical point of view this conclusion follows from the fact that micro parameters determining the MP motion are not dependent on the macro parameters that determine the SP motion energy. This mechanism of irreversibility is deterministic because it follows from the Newton's laws. There is a fundamental difference between deterministic and prob-

abilistic mechanisms. For deterministic mechanism the "coarse-grain" hypothesis isn't required.

Let us explain how can connect the mechanics SP and thermodynamics [5, 6]. In thermodynamics the work of external forces breaks up on two parts. One part is related to the reversible work. Another part of energy goes into heat-ing system. According to it the basic equation of thermodynamics looks like:  $dE = dQ - PdY$ . Here  $E$  is the energy of a system;  $Q$  is the thermal energy;  $P$  is the pressure;  $Y$  is the volume. As we deal with equilibrium systems, then  $dQ = TdS$ , where  $T$  - temperature,  $S$  - entropy. According to the eq. (7), coming into the system energy can be divided on two part. There are energy of relative motion of the SP and its internal energy. It was showed [5] that in thermodynamics to the change of the SP energy of relative motion there corresponds the value of  $PdY$ , and to change of SPs internal energy there corresponds value,  $TdS$ .

Let us take a motionless non-equilibrium system consisting of "R" SP. Each SP consists of a great number of elements  $N_L \gg 1$ , where  $L = 1, 2, 3...R$ ,  $N = \sum_{L=1}^R N_L$ . Then the share of energy, which goes on internal energy increasing, is determined by the expression [5, 6]:

$$\Delta S = \sum_{L=1}^R \{N_L \sum_{k=1}^{N_L} \int [\sum_s F_{ks}^L v_k / E^L] dt\} \quad (15)$$

Here  $E^L$  is the kinetic energy of  $L$ -SP;  $N_L$  is the number of elements in  $L$ -SP;  $L = 1, 2, 3...R$ ;  $R$  is the number of SP;  $s$  is the number of external elements which interact with  $k$  element belonging to the  $L$ -SP;  $F_{ks}^L$  is the force acting on the  $k$ -element;  $v_k$  is the velocity of the  $k$ -element.

The eq. (15) can be viewed as entropy definition. Such definition of entropy corresponds to Clausius entropy definition [9, 10]. Difference consists only that this entropy follows from analytical expression for the change of an internal energy obtained by us on the basis of Newton's laws. From the eq. (15), it is possible to obtain the value of the entropy production and obtain the conditions which necessary for sustain the non-equilibrium system in the stationary state [6]. Thus, we will come to the basic thermodynamic equation if in the equation (7) to carry out standard transition to thermodynamic parameters [5, 9, 10].

Mechanics of SP leads to statistical physics and kinetics. Indeed, the velocities of SP are determined by average values of velocities of MP. The sum of the MP velocities relative to the CM is equal to zero. Thus the internal energy is equivalent to the square of fluctuation of the MP velocities relative to the system's velocity. This means that the dynamics of the SP is expressed through the first and second moments of the motion [9].

## VII. CONCLUSION

The key idea of expansion of the Newtonian mechanics allowing to include the dissipative forces into description, consists in replacements of MP on SP. External simplicity of this idea does not mean its obviousness. Indeed the dynamical characteristics of the system do not follow directly from simple plurality of dynamical characteristics of elements. This is evident from the fact that the structure of the system determines not only its motion but also the collective forces of interactions.

In connection with the construction of the mechanics of the SP requires knowledge of the principles of synthesis of the properties of systems based on the properties of its elements [11]. It is necessary to solving the first question: how to find the SP motion equation on the basis of Newton's laws without attracted of some statistical hypotheses.

It became clear as a result of studying of dynamics of two MP systems that SP mechanics must to be built in space of micro and macro variables. In these variables the energy of SP breaks up on the energy of its motion and an internal energy. The SP motion energy is expressed through macro-parameters. There are co-ordinates and velocities of CM. Its change is connected with the work of the external force acted on the CM of SP. The internal energy is expressed through micro-parameters. The increasing of internal energy is provided by the work of the external forces which change the relative motion of MP. The internal and external forces are independent. Therefore the SP motion energy and internal energy are independent also. Independence internal and external forces tell us about presence two types of symmetry. It is symmetry of space and symmetry of system.

The major factor causing difference of SP dynamics from MP dynamics is a structure and an internal energy. Taking SP as a system's elements we, thereby, have supplied this elements with a new properties - structure and an internal energy. The change of an internal energy provided by the work of collective forces is a cause's difference of SP dynamics from dynamics of MP.

Newton's laws were obtained for models structureless bodies. To use these laws for determine the motion equation for real bodies with the structure; we took a model of SP, consisting of potentially interacting MP. Using the Newton's law for MP, we find the motion equation for SP, taking into account changes in its internal energy. It was done by using the expression for the energy of the SP by transition to the variables that characterize its dynamics. Derivation of the SP motion equation is carried out so. We write the SP energy through independent macro and micro variables. In these variables, it splits into SP's

energy of motion and the internal energy. Differentiating this energy in time, we obtain the equation for the flux of the motion energy and internal energy. From here we come to the SP's motion equation. Dissipative forces are defined through the relation of this work to the SP's motion energy.

Irreversibility is a new property of the SP dynamics. The mechanism of irreversibility is related to the transformation of SP motion energy into the internal energy and the inability of the inverse transformation due to momentum conservation law. Because the SP motion equation obtained on the basis of Newton's laws, the irreversibility of the dynamics of the SP is deterministic. If we neglect the change in internal energy, the motion of the SP will be determined by Newton's motion equation.

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There are both similarities and differences between accepted today a probabilistic explanations of irreversibility [3] and our explanations. In the basis of probabilistic mechanism of irreversibility is a fact of randomization of trajectories of Hamiltonian systems in phase space due to the exponential instability and the hypothesis of "coarse-grain" of the phase space. In the deterministic mechanism of irreversibility both the exponentially instability and mixing in phase space determine the efficiency of transformation of the motion energy into the internal energy. But the irreversibility follows from the momentum conservation law and the non-potentiality of the forces which transform the energy of motion into the internal energy. Therefore the hypothesis about "coarse-grain" of the phase space for deterministic irreversibility is not required.

In accordance with a deterministic mechanism of irreversibility in classical mechanics the concept of entropy is appeared. This entropy corresponds to the empirical entropy offered by Clausius and is consistent with the mathematical form of its probabilistic definition proposed by Boltzmann.

The SP motion equation states impossibility of existence of structureless particles in a framework of the classical mechanics, which is equivalent to infinite divisibility of matter.

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